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Interpretation of the Paediatric ECG

[Link to Paediatric ECG Checklist]

Aim

To provide a systematic approach to interpreting the paediatric ECG, considering rhythm, rate, axes, intervals, wave abnormalities and ST segment changes.

Definition of terms

AVSD: Atrioventricular septal defect
ECG: Electrocardiogram
LBBB: Left bundle branch block
LVH: Left ventricular hypertrophy
LVOT: Left ventricular outflow tract
MI: Myocardial infarction
RBBB: Right bundle branch block
RVH: Right ventricular hypertrophy
SA: Sinoatrial
SSRI: Selective serotonin reuptake inhibitor
TCA: Tricyclic antidepressant
VSD: Ventricular septal defect
WPW: Wolff-Parkinson-White

Target Patient Population

Paediatric patients who require an ECG performed as part of their clinical management

Target Users

Doctors providing care for paediatric patients, who will be responsible for interpreting ECGs as part of their clinical practice.

Assessment

General

A systematic approach is required for interpretation of the paediatric ECG. While modern ECG machines will automatically interpret intervals, duration and axes, these interpretations should only be seen as a guide and using this guideline should aid you in determining not only these features of the ECG, but also rate, rhythm, wave abnormalities and ST segment changes.

Information
You must always check the demographics of the ECG to ensure it is the correct patient. The scale of the ECG is generally (by default) set at 25mm/second on the x-axis and 10mm/mV on the y-axis. All calculations depend on the scale, so it is important to check this prior to interpretation. If set at this scale, it means that one small square (1mm) = 0.04 seconds and 1 large square is equal to 0.2 seconds. Occasionally, with prominent praecordial voltages, the ECG software or cardiac physiologist will prompt the operator to adjust the scale to 5mm/mV for example, to prevent one lead voltage overlapping with another.

Rate
An estimate of the heart rate can be determined by dividing 300 by the number of large squares between the R waves. The normal ranges for heart for various paediatric ages are shown in Table 1. A list of causes for paediatric tachycardia and bradycardia is displayed in Table 2.

Age	Heart Rate
New-born	90-180
6 months	110-180
1 year	80-160
2 years	80-140
4 years	80-120
6 years	75-115
8 years	70-110
10 years	70-110
12 years	60-110
14 years	60-100

Table 1. Normal paediatric heart ranges

Tachycardia	Bradycardia
Sinus tachycardia	Sinus bradycardia
Supraventricular tachycardia	Nodal rhythm
Ventricular tachycardia	Second degree AV block
Atrial fibrillation	Third degree AV block
Atrial flutter	

Table 2. Aetiology of paediatric tachycardia and bradycardia

"Sinus rhythm" implies that the SA node is acting as the pacemaker for the entire heart. To be interpreted as "Normal Sinus Rhythm" the following criteria must be met:

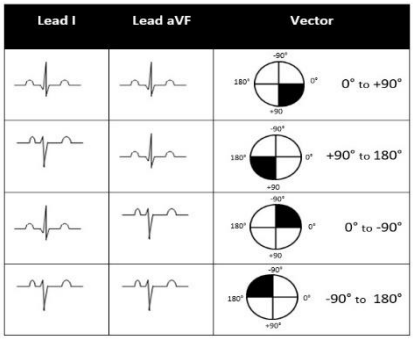
1. Normal rate for age.
2. There must be a P wave in front of every QRS complex.
3. The P wave axis must be in the range of 0 to +90 degrees. To meet this criterion the P wave should be upright in leads II, III and aVF.
4. There should also be normal P wave morphology which indicates that the current is moving away from the SA node in a normal pattern and time.
5. The PR interval should be normal.

Sinus arrythmia: Normal finding, irregular rate in which the variation of the R-R ratio is greater than 0.12 seconds. This does not warrant a cardiology referral.
Sinus tachycardia: Consider sepsis, shock, thyroid dysfunction, and medications.
Sinus bradycardia: Consider raised intracranial pressure, medications.

QRS Axis
The limb lead vectors determine the axis. A positive QRS complex in leads I and aVF results in an axis of between 0 and 90 degrees and this is normal. Left axis deviation occurs when the QRS vector falls between -30 and -90 degrees. It can be caused by AVSD, LVH and tricuspid atresia. Mild left axis deviation (-30 degrees) is normal from puberty to adulthood. Right axis deviation occurs when the QRS axis is between +90 to +180 degrees. In older children right axis deviation can be caused by RVH. The range of QRS measurements by age is shown in Table 3.

Age	QRS Mean Degrees (Range)
1 week to 1 month	+ 110° (+30 to + 180)
1 to 3 months	+ 70° (+10 to +125)
3 months to 3 years	+ 60° (+10 to +110)
Older than 3 years	+ 60° (+20 to +120)
Adults	+ 50° (-30 to +105)

Table 3. Ranges of QRS by age



T Wave Axis

The T wave is usually upright in V1 at birth but should be negative by the 4th day of life. If the T wave remains upright in V1 this may indicate right ventricular hypertension. It should remain negative as an infant, and then become progressively more anterior. T waves in V5-V6 should be upright.

PR Intervals

The PR interval is measured from the start of the P wave to the beginning of the QRS complex (PQ interval) in lead I. The PR interval according to heart rate and age is shown in Table 4. The normal range is 110-200msec or 5 small squares.

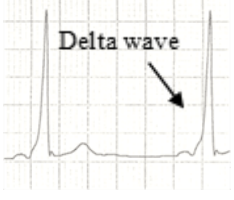
Rate	0-1mo	1-6mo	6-12mo	1-3yr	3-8yr	8-12yr	12-16yr	Adult
< 60						0.16 (0.18)	0.16 (0.19)	0.17 (0.21)
60-80					0.15 (0.17)	0.15 (0.17)	0.15 (0.18)	0.16 (0.21)
80-100	0.10 (0.12)				0.14 (0.16)	0.15 (0.16)	0.15 (0.17)	(0.15) (0.20)
100-120	0.10 (0.12)			(0.15)	0.13 (0.16)	0.14 (0.15)	0.15 (0.16)	0.15 (0.19)
120-140	0.10 (0.11)	0.11 (0.14)	0.11 (0.14)	0.12 (0.14)	0.13 (0.15)	0.14 (0.15)		0.15 (0.18)
140-160	0.09 (0.11)	0.10 (0.13)	0.11 (0.13)	0.11 (0.14)	0.12 (0.14)			(0.17)
160-180	0.10 (0.11)	0.10 (0.12)	0.10 (0.12)	0.10 (0.12)				
> 180	0.09	0.09 (0.11)	0.10 (0.11)					

Table 4. PR interval according to heart rate and age (Upper limit normal in brackets)

Prolonged PR interval indicates 1st degree heart block and can represent a normal finding. However, myocarditis, toxicities, congenital lesions, hyperkalaemia, and ischemia should be considered.

Short PR interval may be seen in Wolff-Parkinson-White (WPW) syndrome and glycogen storage disease (e.g. Pompe disease).

If there is a short PR interval the QRS complex should be checked for the presence of a delta wave indicating WPW.



P Wave
The P wave amplitude should be less than 3mm (3 small squares). The maximum P wave duration is <0.10 seconds in children and 0.08 seconds in infants. Tall P waves (P Pulmonale) indicate right atrial dilatation while prolonged/wide P waves (P Mitrale) indicate left atrial dilatation.

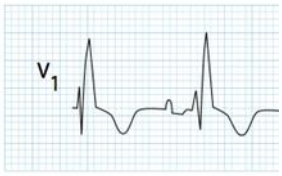
QRS Complex
The QRS complex represents ventricular depolarisation and consists of the Q, R and S wave. It is measured in lead II from the onset of the Q wave to the termination of the S wave. The duration of the complex increases with age and bradycardia. A duration of greater than 0.12 seconds/3 small squares is considered pathologic in children. The QRS duration may be significantly prolonged in children who have had cardiac surgery.

A bundle branch block consists of a wide QRS complex and interruption of the flow of the R/S waves. A partial bundle branch block (without QRS prolongation) is considered a normal finding). A bundle branch block is best interpreted in leads V1 and V6 using the mnemonic **William Morrow**. The letters 'W' and 'M' relate to the deflection of the QRS complex in leads V1 and V6 respectively with the 'W' being negatively deflected and the 'M' being positively deflected.

A positive deflection or rSR pattern in lead in V1 with a negative deflection in V6 indicates a right bundle branch block (RBBB) while a negative QRS in lead V1 and a positive deflection in V6 indicates a left bundle branch block (LBBB).

A RBBB may be caused by right ventricular overload with the commonest aetiology being a secundum ASD or rarely with other heart disease such as Ebstein's anomaly. There is a dominant R' with the apostrophe indicating a taller second R wave. A RBBB can commonly be seen after VSD or tetralogy of Fallot repair.

A LBBB is rare in children who have not had cardiac surgery and is commonly seen after surgical LVOT resection (e.g. myotomy or myectomy)



rSR' pattern in lead V1

The QRS complexes should then be observed for hypertrophy. There are numerous different formulae to calculate hypertrophy but a good "rule of thumb" is to focus on the voltages in V1 and V6 for RVH and LVH respectively.

- To interpret **LVH (abnormal left ventricular large voltage) – Use only V6** (the *left* most precordial lead)
- To interpret **RVH (abnormal right ventricular large voltage) – Use only V1** (the right most precordial lead)

Upright T wave in V1: In the first week of life, this is normal. Between week 1 and adolescence, this is *ABNORMAL* and suggests RVH. A qR pattern in V1 (small q wave, tall R wave) is also highly specific for RVH but can be normal in 10% of neonates.

LVH is suggested by a tall R wave in lead V6. The normal R wave amplitude measurements according to age for V1 and V6 are shown in Table 5.

	0-1mo	1 mo – 12 mo	1 y – 12 y
V1 R amplitude upper limit of normal)	25mm	20mm	18mm
V6 R amplitude (upper limit of normal)	21 mm	20 mm	24 mm

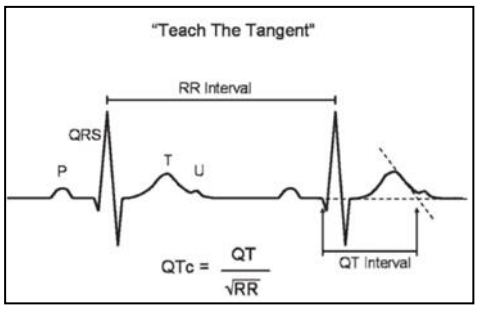
Table 5. R wave amplitude measurements by age in lead V6

Note: Prominent praecordial voltages suggesting both RVH and LVH can be a variant of normal in the 6 months to 3 years age group, but may also suggest biventricular hypertrophy, from a haemodynamically significant VSD for example.

QT Interval

The QT interval should be measured in lead II from the beginning of the Q wave until the end of the T wave. There is variance with heart rate, and it may be corrected (QTc) using Bazett's formula. The end of the T wave should be identified using the "Teach The Tangent" method as shown below. A tangent is drawn to the steepest slope of the last limb of the T wave in lead II. The end of the T wave is the intersection of the tangent with the baseline.

Bazett's Formula: QTc = QT Measured/ √RR Interval



Teach the Tangent (Postema, 2008)

At heart rates over 120bpm, this formula can be unreliable. The **manually calculated** QTc should be greater than 340 and less than 450msec

QTC Prolongation: Long QT syndromes, head injury/concussion, drugs (e.g. amiodarone, TCA's, fluconazole, erythromycin, methadone metoclopramide, haloperidol, ondansetron, SSRI's) or rarely myocarditis.

ST Segment

The ST segment represents the interval between ventricular depolarization and repolarization. It begins at the end of the S wave (J point) and terminates at the beginning of the T wave and is iso-electric in a normal ECG. However, elevation or depression up to 1mm may be normal in infants and children. In the praecordial leads, elevation or depression up to 2mm is considered normal. A shift above 2mm should be considered pathologic as shown in the Table 6.

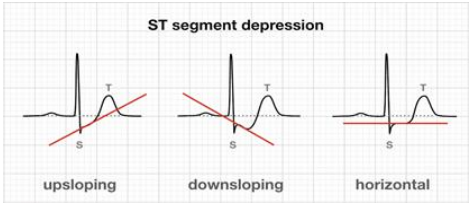
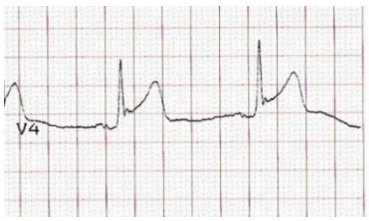
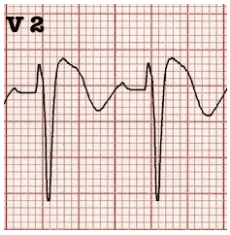
		
ST Segment Depression	Pericarditis	Brugada Type 1

Table 6. Examples of pathologic ST elevation

Pericarditis is inflammation or infection of the pericardium, the thin membrane that surrounds the heart. There are 4 stages of ECG changes for acute pericarditis.:

- *Stage 1* – Widespread ST elevation and PR depression with reciprocal changes in aVR (occurs during the first two weeks)
- *Stage 2* – Normalisation of ST changes; generalised T wave flattening (1 to 3 weeks)
- *Stage 3* – Flattened T waves become inverted (3 to several weeks)
- *Stage 4* – ECG returns to normal (several weeks onwards)

T Wave

The T wave represents repolarization of the ventricles. There is a physiological inversion in V1-V3 after birth which returns to upright in reverse order during childhood. Depending on the age of the child, the T waves in V1-V4 may not have reversed, and this can be a normal variant. However, they should be upright in leads V5 and V6 in a normal ECG. Persistent inversion of the T wave in V1 is a normal variant. Upright T waves in V1 in children between 4 days and 4 years of age are usually pathologic and indicative of RVH.

Tall, peaked T waves could be as a result of hyperkalaemia, LVH, volume overload, stroke, posterior MI. Flat, low T waves can be secondary to hypothyroidism, hypokalaemia, hypo/hyperglycaemia, pericarditis, myocarditis, ischaemia, digitalis effect (reverse tick), Long QT syndrome or normal in new-borns.

If the ECG is abnormal or there is clinical concern, discuss with the local consultant/registrar. Cardiology opinion can be sought following this, after local consultant review via ecg.review@olchc.ie

Links to useful websites

Greater Glasgow and Clyde
Don't Forget The Bubbles
Starship Child Health

Companion Documents

Paediatric ECG Checklist

Link to Reference List